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Multi-View Interaction Modelling of human collaboration processes: A business process study of head and neck cancer care in a Dutch academic hospital

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A B S T R A C T

In the healthcare domain, human collaboration processes (HCPs), which consist of interactions between healthcare workers from different (para)medical disciplines and departments, are of growing importance as healthcare delivery becomes increasingly integrated. Existing workflow-based process modelling tools for healthcare process management, which are the most commonly applied, are not suited for healthcare HCPs mainly due to their focus on the definition of task sequences instead of the graphical description of human interactions.

This paper uses a case study of a healthcare HCP at a Dutch academic hospital to evaluate a novel interaction-centric process modelling method. The HCP under study is the care pathway performed by the head and neck oncology team. The evaluation results show that the method brings innovative, effective, and useful features. First, it collects and formalizes the tacit domain knowledge of the interviewed healthcare workers in individual interaction diagrams. Second, the method automatically integrates these local diagrams into a single global interaction diagram that reflects the consolidated domain knowledge. Third, the case study illustrates how the method utilizes a graphical modelling language for effective tree-based description of interactions, their composition and routing relations, and their roles. A process analysis of the global interaction diagram is shown to identify HCP improvement opportunities.

The proposed interaction-centric method has wider applicability since interactions are the core of most *multidisciplinary patient-care processes*. A discussion argues that, although (multidisciplinary) collaboration is in many cases not optimal in the healthcare domain, it is increasingly considered a necessity to improve integration, continuity, and quality of care. The proposed method is helpful to describe, analyze, and improve the functioning of healthcare collaboration.

1. Introduction

Nowadays, healthcare services require close collaboration of healthcare workers from different (para)medical disciplines and departments. Improved support of healthcare collaboration through Information Technology (IT) is only possible if the essence of collaboration can be captured and understood [1–4]. The current research contributes to the graphical description of healthcare collaboration to enable deep understanding of its functioning.

Business Process Management (BPM) is a prominent way to gain deep understanding of the functioning of organizations [5]. The graphical description of business processes in models (i.e. business process modelling) is the core concept in achieving this better understanding [6]. In various industries and services, BPM is most commonly applied to workflow processes, which are well-structured and repetitive business processes [6,7]. Existing graphical workflow-based process modelling tools focus on the definition of the tasks and their ordering relations within the business process. Their primary purpose is to create a standard workflow model that is defined once and then serves as an executable specification for a workflow management system to enable automated process support [8]. This paper argues that such an approach does not suit the modelling of business processes that require intensive collaboration, so-called artistic [9] or human-driven processes [10]. In this research, such processes are defined as human collaboration processes (HCPs). A HCP is a coordinated collaboration effort where humans perform several related and intermittent workplace interactions, in which they may play different roles. Therefore, a HCP consists of a process structure of human

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interactions. Examples of human interactions are meetings, discussions, consultations, conversations, etc.

Human interactions increasingly characterize the contemporary workplace, as the structure of organizations has become more flat, less hierarchical, more fluid, and even virtual [11]. This is also true for the healthcare domain where a move towards more flexible organizational structures with a focus on teamwork and collaboration can be observed [12]. For healthcare processes, a general distinction can be made between organizational processes (e.g. clinical workflows like medical order entry), and medical diagnosis and treatment processes [13]. In [4], the authors name the latter *multidisciplinary patient-care processes*. These processes are good examples of HCPs since they require a wide range of interactions within and across (para)medical disciplines and departments in diagnosis and treatment [13–15]. With healthcare HCPs, the primary purpose of business process modelling is to capture and define accurately the essence of healthcare collaboration (i.e. the interaction structure) as a necessary precursor for analysis and improvement of the HCP. This requires novel modelling tools because of the different nature of the business activity (i.e. collaboration instead of task sequence).

This paper introduces, applies, and evaluates a novel interaction-centric modelling method for HCPs through a case study of a healthcare HCP at the *University Medical Center Groningen* (UMCG), the largest Dutch academic hospital. The healthcare HCP under study is the Head and Neck Oncology (HNO) *care pathway*.[1] In this HCP, numerous interactions take place between the different involved healthcare workers (a group named "the HNO team"). The HCP runs because of joint experience and collaboration, which brings on the execution of the interactions. However, the awareness about these interactions is based on tacit domain knowledge.[2] The (organizational) problem is that there is no explicit process definition of the target HCP's interaction structure. Due to this, it has been very difficult for the HNO steering team to analyze and improve the HNO care pathway.

The proposed modelling method is the Multi-View Interaction Modelling (MVIM) method, which is designed to capture and model a HCP's interaction structure (i.e. interactions, their composition and routing relations, and their roles). For the successful evaluation of the method in the case study, there are three main requirements. First, an effective interaction description capability is needed. Second, the MVIM method should be able to make explicit, in graphical models, the tacit domain knowledge of the HNO team members.[3] Third, the method should contribute to an improvement of the HNO care pathway.

The *main contribution* of this paper is the MVIM method as a novel interaction-centric modelling tool and the evaluation of its effectiveness in practice. The remainder of this paper is structured as follows. Section 2 presents theoretical background including related work. Next, Section 3 outlines the adopted research methods including a description of the case study and the target healthcare HCP (i.e. the HNO care pathway). Section 4 introduces the MVIM method and describes its application to the HNO care pathway. After, Section 5 reports on the practical results with details in Appendix C. Section 6 reports on the evaluation of the proposed method. Section 7 presents a discussion with generalization and implications of the results in the broader healthcare domain. Finally, Section 8 gives conclusions and highlights future research.

2. Theoretical background

2.1. The TALL modelling language

An interaction-centric business process modelling language named The Agent Lab Language (TALL) [18–20] supports the MVIM method. The language explicitly recognizes human interaction as the core activity in collaborative organizational work. Within the context of a HCP, a human interaction is operationally defined as a joint activity between two or more agents (i.e. interaction participants) that is undertaken to reach individual and/or joint goals. In line with [21], where (the design of) collaboration is explored in detail, this means that interaction is a key condition for successful completion of a HCP. The authors mention that without interaction, participants cannot define their goal, commit to it, or attune their behaviors toward goal attainment. Depending on the media and communication channel, human interactions can be of different types (e.g. synchronous/asynchronous, verbal/non-verbal, physical/virtual) and forms (e.g. discussion, conversation, consultation). Moreover, depending on the involved agents, human interactions can be intra- or inter-organizational. The interactions studied in the HNO care pathway are intra-organizational (but inter-departmental).

There are four main (agent-oriented) concepts in TALL: interactions, roles, agents, and behaviors. The interactions in a HCP are modelled in the interaction structure (IS) diagram (see Fig. 1). The IS diagram is a hierarchical interaction structure, in which interactions are related by composition (one interaction being part of another) and routing (one interaction must be completed before, in parallel with, or instead of another interaction). The IS diagram has a tree layout, which means interactions appear at a certain level. The root level, which starts at the top, is level zero.

A parent interaction completes when its child interactions complete according to the specified routing relation. The routing relation is specified using a routing type symbol, which graphically appears below parent interactions (see Fig. 1). Formally, the routing type is an attribute of the parent interaction. The supported routing types are sequential routing (SEQ), parallel routing (PAR), and exclusive (non-deterministic) choice (XOR).

Decision rules can be attached to the routing types to enable rule-based execution of a set of sibling interactions. Decision rules can for instance be used to achieve an exclusive deterministic choice (XOR_d), or to make an inclusive choice for N-out-of-M sibling interactions. In the latter case, when $N \geqslant 2$, the children are executed in sequence (SEQ_d) or in parallel (PAR_d). In Fig. 1, interaction C is completed either by interaction D or by interaction E. The decision rule attached to the XOR_d routing type of interaction C selects only one of these interactions. The following is the complete list of interaction attributes: *Id* (unique identification), *Label* (interaction name), *Routing Type* (routing relation), *Parent* (Id of the interaction's parent), and *Children* (number of children).

For each elementary interaction (i.e. interactions without children in the tree), it is indicated which roles or generic participant types are involved. Roles are depicted by ellipses and are attached to the lines outgoing the hexagon (see Fig. 1). In TALL, an interaction does not exist without at least two roles being bound to it. Agents are part of a formal structure within their organization, which is usually based on the structure of official roles or job titles. It is the role that assigns certain responsibilities to an agent and requires their involvement in interactions. Therefore, role specification is important to divide responsibilities and ensure interaction execution. The initiator role is the role that either starts or leads

[1] A care pathway is a multidisciplinary outline of anticipated care, placed in an appropriate timeframe, to help a patient with a specific condition or set of symptoms move progressively through a clinical experience to positive outcomes [16].

[2] Tacit domain knowledge is individual knowledge of experience, which is mainly intangible and often resides in the heads of employees [17].

[3] The (internal) process of transformation of tacit knowledge into formal explicit knowledge is an important research subject in the field of Knowledge Management (KM). In this paper, the focus is on the practical use of (interaction-centric) business process models that formalize tacit domain knowledge, not on the KM aspects.

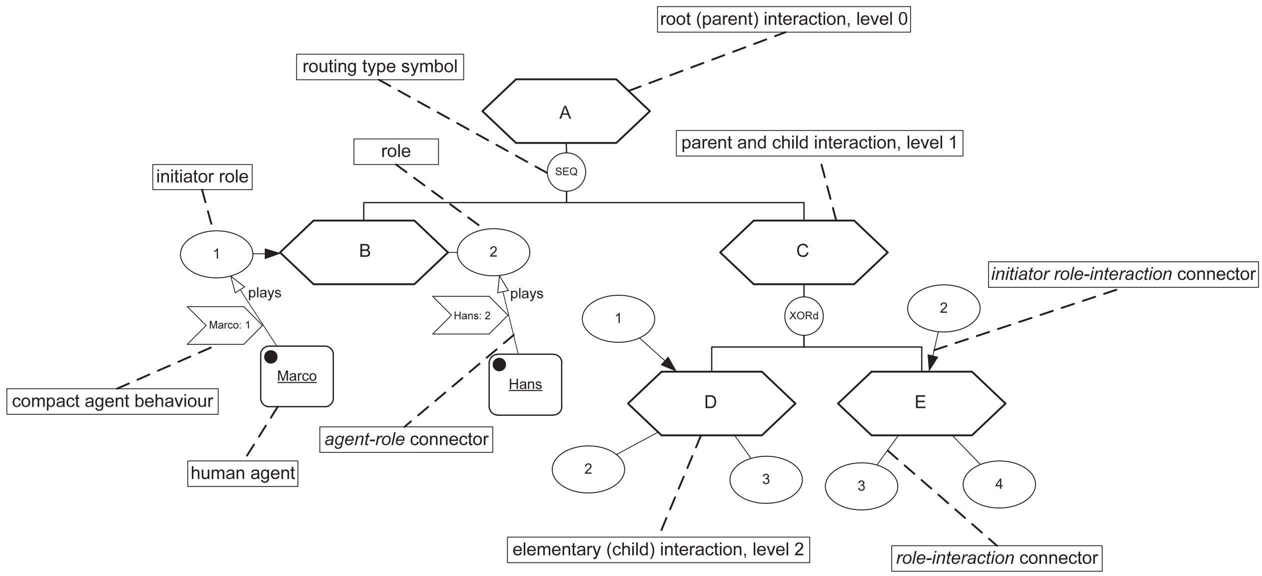

Fig. 1. Graphical representation of TALL's main modelling concepts.

an interaction, and is identifiable by the role-interaction connector with a filled arrowhead (see Fig. 1). Roles have two attributes: *Label* (role name) and *Initiator* (yes/no). The elementary interactions are completed by the coordinated execution of the behaviors performed by the agents playing the involved roles. Agents are depicted by rounded rectangles and their behaviors are depicted by arrow rectangles that appear at the tail of the agent-role connector (see Fig. 1). Each arrow rectangle is a compact representation of an agent behavior (AB) diagram, which describes the local (communicative and non-communicative) activities that the agent executes as part of the interaction.

With the IS and AB diagrams, TALL separates between two levels of linked process representations. The IS diagram allows to specify *what* to perform in terms of a HCP's interaction structure. The associated AB diagrams allow to specify *how* the interactions are performed in terms of the local behaviors of the agents that are assigned to the roles in the IS diagram. The IS diagram introduces a higher-level (relatively stable) notion of process that separates the interaction specification from the possible (relatively dynamic) ways to perform an interaction. This is based on the motivation that novel modelling tools for HCPs should, at first, abstract from the level of individual activity representation. These can still be represented at a lower level, via the AB diagrams, when the interaction structure of the HCP has been defined.[4] In this paper, the focus is on the IS diagram as a tool to describe the interaction structure of the HNO care pathway. The interested reader is referred to other papers [19,20] for a more detailed discussion on agent behavior modelling.

Besides the IS an AB diagrams, there are other types of diagrams in the TALL modelling language, which allow to capture other aspects of a HCP and its organizational environment. One of these diagrams, which is applied in this paper (see Section 4.2), is the Agent Structure (AS) diagram to capture the structure of the organizational population under consideration. In this diagram, all involved business entities are modelled as agents whose nature can be individual (i.e. human agents) or collective (i.e. synthetic agents). Human agents represent people in the business domain, and synthetic agents represent organizational units (e.g. departments, teams) or organizations. A synthetic agent is a composite agent that consists of one or more internal (human or synthetic) member agents.

2.2. Related work

The MVIM method is a methodical approach to conduct a business process study. This section contrasts the method with several recent empirical business process studies in the healthcare domain through a discussion of traditional (workflow-based) process modelling methods and languages.

A common feature in most process modelling methods is the use of a graphical modelling language to describe business processes. Existing graphical workflow-based process modelling languages like BPMN [22], WS-BPEL [23], Petri nets [24], UML activity diagrams [25,26], EPCs [27] and IDEF0 [28], which are the most commonly applied in the BPM field, focus on the definition of task flows (i.e. tasks and their ordering relations). Although most of these languages (now) provide notations to model collaboration and/or interaction, they have not been designed with interaction in mind. In most of these languages, interactions are modelled through the specification of message exchange, that is, they are modelled as mere 'connected' communicative tasks that are mixed with the specification of the non-communicative tasks. In the case of numerous interactions with many participants, it becomes difficult to see, in a workflow model, where interaction takes place, between whom, and what the relations are between the interactions [20]. This applies especially to large diagrams with increasing numbers of participants and interactions [29]. Thus, the graphical representation of interaction structures is weak in existing (task-centric) workflow-based process modelling languages. Several authors confirm that existing graphical workflow-based process modelling languages are appropriate for modelling business processes that display complex task flows (i.e. workflow processes) but are less appropriate for modelling business processes that involve the interaction of a multitude of actors (i.e. HCPs) [29–33].

Most empirical business process studies are concerned with workflow processes. Several recent healthcare process studies take a workflow perspective [34–39]. In BPM research, the software engineering community is interested in the technical realization of business processes in software systems [6]. Workflow-based

[4] For example, a meeting is difficult to model prescriptively as a graph of individual activities in a first modelling phase. However, in a second modelling phase, it is possible to specify the individual utterances of the interaction participants in AB diagrams.

process models are most useful when the business activity is procedural of nature [40]. The supporting workflow management system uses the prescriptive model to enact the process in the same way for each case that runs through the process, which enables efficient and effective process execution. A number of research efforts in the software engineering field focus on IT support of unstructured (informal) workflow processes [41–47], which require more flexibility in their execution. Thus, these workflow studies focus on more than only procedural processes, which is important for the application of business process support and automation in less structured application domains. In the healthcare domain, such workflow studies can also be observed [2,13,48,49]. However, in these studies the desired process flexibility is built into the architecture of the supporting IT system. In general, current workflow studies are mostly technology-oriented works, which focus on the effectiveness or efficiency of workflow management systems [50]. In [51], the author states that businesses have overemphasized the role of IT while they underestimate the importance of a clear understanding and critical analysis of their human processes. Extant research and practice in the BPM field does not properly address the class of problems associated with the modelling and analysis of human interactions in organizations. The adopted modelling tools are task-centric rather than interaction-centric. As argued in the introduction, healthcare HCPs have a different nature and modelling purpose. The MVIM method is supported by the TALL modelling language. The language considers the interaction (performed by multiple actors) instead of the task (performed by a single actor) as the core activity in a business process.

Traditionally, a business process study starts with a description phase to capture the AS–IS or current business processes. This phase usually consists of the following activities: (1) the business process modeller visits the target organization, (2) reads the existing documentation, (3) conducts a series of interviews, and (4) studies and represents the gathered information in process models [6,52]. The description phase is usually followed by an analysis phase to identify bottlenecks or improvement options in the AS–IS model. Finally, the redesign phase creates a TO-BE process model based on the results of the analysis phase and/or predefined objectives (e.g. to conform to a new corporate strategy or to suit a new IT system).

The main innovation of the MVIM method is the focus on the modelling of collaboration and interaction. In line with this focus, the proposed method differs from traditional task-centric methods, especially with regard to the nature of the activities in the description phase. In a HCP, different participants may have different views on the process. One of the characteristics of the HNO care pathway, described in Section 3.1, is the existence of local process views. Healthcare workers are knowledgeable about their interactions and responsibilities but do not have a complete view of the overall HCP. The HCP functions because the healthcare workers playing the roles in the interactions know themselves what to do. Thus, a HCP has an emergent bottom-up nature. Traditional methods do not model explicitly the local views of the process participants [20]. The MVIM method considers that not modelling the local views of the process participants (i.e. the subject matter experts) means losing the essence of what makes the process work. Thus, the MVIM method collects and models local interaction views in local IS diagrams, and then automatically consolidates them in a global IS diagram using an implemented algorithm (see Section 4.4). This results in a model that minimizes the gap between the actual HCP and the modelled HCP thus providing a rich base for the analysis phase. A local IS diagram is defined as an individual diagram that depicts the local (i.e. incomplete and restricted) interaction view of a single process participant. It can be considered a segment of the HCP under study. A global IS diagram does not take the point of view of a particular process participant but shows an integrated interaction view.

3. Methods

3.1. Case study: setting and process description

The research objective of this paper is to introduce, apply, and evaluate the MVIM method. As mentioned in Section 1, a case study at the UMCG is conducted to achieve this objective. A case study is defined as an empirical inquiry that investigates a contemporary phenomenon within its real-life context [53]. Case studies emphasize the rich, real-world context in which the phenomenon of interest occurs [54,55]. The stated research objective requires the in-depth study of a healthcare HCP in its real-life context. Therefore, a case study is an effective research strategy. A case study research strategy allows the MVIM method to be presented and evaluated in the context of application in close collaboration with the people in the field [56]. The close connection with reality is considered important to make sure the MVIM method is effective and purposeful to address practical problems.

Currently, in the Netherlands, approximately 2700 cases of head and neck cancer are diagnosed yearly and the incidence of this ailment has been rising over the past few decades [57]. The main risk factors for the emergence of a tumor in the mouth, pharynx or larynx are smoking, chewing tobacco, drinking alcohol, or a combination of these. Head and neck cancer is the work domain of both the *ENT specialist* (ear, nose, throat) and the *maxillofacial surgeon*. In the Netherlands, the care for head and neck cancer patients is organized into eight specialized treatment centers, one being the HNO team in the UMCG. A tumor in the head and neck area may have physical (e.g. problems with breathing, eating, drinking, speaking, damage to the physical appearance, etc.), emotional, psychosocial, and relational effects for the patient and his/her key relatives. Because of the complexity of the care, a relatively large number of over 40 (para)medical disciplines is involved in the HNO care pathway, which together form a multidisciplinary team. The HNO team works according to national guidelines set up by a cooperation network named the Dutch Co-operative Head and Neck Group (NWHHT[5]) in which all eight Dutch HNO treatment centers participate. The primary goal of the NWHHT is to advance the quality of the HNO care in the Netherlands. The NWHHT not only develops guidelines but also performs internal evaluations by means of accreditations.

The HNO care pathway deals with the human interactions in the outpatient and inpatient diagnosis, treatment and/or consultation, and follow-up of patients suffering from head or neck cancer once they are referred to the UMCG. Thus, the scope of the healthcare HCP under study is the intramural care within the UMCG for this specific patient group. On a high level, the studied interactions are of three generic types: (1) interactions between healthcare workers and patients (e.g. medical examinations, treatments, consultations), (2) interactions between colleagues within or across (para)medical disciplines or departments (e.g. meetings, consultations, casuistry), and (3) interactions between healthcare workers and information systems (e.g. activity registration, activity planning, medical file processing). Interactions belonging to these three generic types are initiated based on formal responsibilities. As explained in Section 2.1, these formal responsibilities are assigned to healthcare workers via formal roles (i.e. job titles). The practical goal of the business process study presented in this paper is to identify improvement opportunities that can be used to structur-

[5] http://www.nwhht.nl/.

ally improve collaboration and interaction in the target healthcare HCP in the future. In this context, the formal work-related interactions are most valuable since they remain relatively stable in terms of occurrence. This was confirmed by a *maxillofacial surgeon oncologist* and a business line manager, who served as key informants throughout the study. Section 3.2 provides more detail on the adopted data collection methods, which includes key informant sessions. An important interaction trigger in a care process, besides the formal work-related trigger, is exception handling. Section 6 explains in more detail how exceptions can be tackled in the MVIM method.

Based on an exploration of practice (see Section 3.2 for detail), the following distinctive characteristics of the HNO care pathway were identified.

1. The HNO care pathway is ***collaborative***.
   Head and neck cancer management requires close and seamless collaboration among the diagnostic and treating disciplines [58]. Healthcare workers rely on each other's expertise, experience, and resources when making decisions with regard to patient care. A wide range of interactions within and across (para)medical disciplines and departments is required in terms of information sharing, consultation, and combined diagnosis and treatment [13–15]. In the HNO care pathway, even the simplest activities, like an endoscopy, require interaction among different disciplines.

2. The HNO care pathway is ***multidisciplinary***.
   In multidisciplinary patient care, team members have different professional backgrounds and functional areas of expertise. Moreover, they are often concerned with different aspects of patient care and are involved in different phases of the care process. Distinctive properties of multidisciplinary collaboration are that (i) medical disciplines and their employees maintain their own identity in terms of their methodical approach, theoretical perspectives, responsibilities and focus areas [59], (ii) employees work relatively independently [3], and (iii) employees have differing perceptions of teamwork [59,60]. Based on these properties, the HNO team members have their own local (i.e. restricted and incomplete) views.

3. The HNO care pathway is ***complex***.
   The HNO care pathway consists of a multitude of interactions in intricate arrangement. Interactions are interrelated in terms of both routing and composition. Interactions in and across (para)medical disciplines and/or departments may run in conjunction with each other, certain interactions may have to be completed before others, certain interactions may have to be repeated, and certain interactions may be part of other interactions.

4. The HNO care pathway is ***dynamic***.
   The tasks of the HNO team members are dynamic.[6] Due to newly discovered symptoms of a specific disease, the need for further diagnosis, or new medical knowledge, treatment plans must be tailored to the individual needs and circumstances of the patient. Moreover, they require frequent adjustment (e.g. to suit national guidelines) and joint decision-making [14,15].

5. The HNO care pathway is ***large-scale***.
   The HNO care pathway involves healthcare workers from over 40 (para)medical disciplines and departments, and consists of over 400 identified interactions performed by over 120 team members.

[6] In this context, dynamics refers to the stability or instability of the tasks in a business process. The tasks in a dynamic business process change frequently and unpredictably whereas the tasks in a static business process do not change very often; they either remain the same or change very slowly.

3.2. Data collection: description phase

Case study research allows the use of several data collection methods [61]. The UMCG case study draws on three data collection methods: desk study of organizational documentation, key informant sessions, and interviews with healthcare workers.

As indicated in Section 3.1, two key informants were used throughout the study. Key informants, sometimes referred to as strategic informants, are expert sources of information who are able to provide valuable information and insights usually due to a position of responsibility and influence [62]. Both key informants are members of the HNO steering team. In this position, they are interested in the continuous improvement of the HNO care pathway and have an important managerial role in any improvement project. Based on this formal position, the key informants have profound knowledge of the case setting, the HNO care pathway, and the involved healthcare workers. Thus, they were able to provide extremely valuable (managerial) information and feedback. Moreover, they were able to facilitate the interview process in terms of building internal commitment. Although key informant sessions are similar to unstructured interviews, they are different in that the informants are chosen for strategic (in this study based on managerial position and influence) rather than representational reasons and that their content differs over time [63]. During this research, sessions with the two key informants took place in the preliminary (exploratory) and final phases of the case study with different contents. This is described in more detail in the remainder of this paper.

The data collection process started with an exploratory phase in which organizational documentation (i.e. organization's structure explanatory documents and medical protocols) and sessions with the key informants took place. To facilitate the data collection process, the key informants arranged for the first author to have an office and computer within the UMCG. The result of this exploration of practice was:

1. a better understanding of the organizational problem (i.e. no proper basis for the analysis and improvement of the HNO care pathway);
2. a better understanding of the HNO care pathway in terms of the characteristics in the previous section;
3. the identification of the (para)medical disciplines/departments and role names (i.e. job titles) involved in the HNO care pathway;
4. the creation of a preliminary high-level IS diagram of the HNO care pathway, which provides a general overview of the healthcare HCP in terms of its main default interactions (see Appendix A for the diagram and Section 4.2 for a description).

Besides the key informant sessions, interviews with healthcare workers (i.e. process participants) were the main source for collecting process information. Although one of the key informants, being a *maxillofacial surgeon oncologist*, is also a healthcare worker in the HNO care pathway, a different *maxillofacial surgeon oncologist* was selected for the interviews. The identified (para)medical disciplines/departments and role names helped to select a representative group of healthcare workers for the interviews. This resulted in the selection of 43 healthcare workers. The selected interviewees were representative of each department and hierarchical level involved in the HNO team including medical specialists, paramedical staff, and clerical staff. Section 4.2 provides more detail on the involved (para)medical disciplines/departments and the selection of the interviewees. The objective of each interview was to model the local interaction view of the interviewee in a local IS diagram. In this way, multiple local IS diagrams, in which the tacit domain knowledge of the interviewees is formalized, are produced that are to be automatically integrated into a global IS diagram.

The conducted interviews took the form of mini-workshops in which the researcher and the interviewee co-produced a local IS diagram in a face-to-face setting. The presence and active engagement of the researcher made the creation of the local IS diagrams efficient. In this regard, the interviews took a romantic approach [64]. In the romantic interviewing approach, the interviewee is seen as a participant with whom the researcher actively interprets and constructs reality. The romantic approach is opposed to the instrumentalist interviewing approach in which the interviewee is seen as a subject and the interview focuses on the elicitation of facts with a relatively passive role of the researcher. The advantage of the constructed and co-created nature of the romantic approach is that the risk of the discourse spiralling into abstractions, generalities, and cultural scripts is reduced. In the UMCG case study, the joint process modelling made the interviews more concrete in the sense that tacit domain knowledge was made explicit, thereby objectifying it for later use and analysis.

Two modellers conducted the interviews: the first author and a master student. A few days before the interviews took place, each interviewee received an e-mail explaining the objective and focus of the interview, and the request to think about their (local) interactions in the HNO care pathway. The e-mail also gave some typical examples of the three generic types of human interaction mentioned in Section 3.1. The interview process was as follows. During each interview, the modeller started with a short self-introduction, followed by an explanation of the TALL modelling notations using the high-level IS diagram that served as input to each interview. Only two key questions were prepared beforehand. The first question asked the interviewee to illuminate his/her position and responsibilities. Globally, the HNO care pathway consists of three phases: diagnostic phase, hospitalization/treatment phase, and follow-up phase. The second question inquired in which phase(s) of the HNO care pathway the interviewee was (mostly) involved. The interviewer then used the high-level IS diagram to facilitate a focused walkthrough discussion of the HNO care pathway. During the walkthrough, the interviewee was asked to name and describe his/her own interactions, relevant interactions of colleagues he/she knows of, composition and routing relations between the interactions, and the allocation of roles over the named interactions. In the walkthrough discussion, the focus was on those interactions corresponding to one of the three identified generic types of interaction. In collaboration with the interviewee, the modeller then augmented the default interactions in the high-level IS diagram to make the collected domain knowledge explicit and produce a local IS diagram.

The average time of each interview was 2 h. Each local IS diagram was immediately validated together with the interviewee. Because of the open but guided nature of the interviews, they can be classified as unstructured interviews [65]. In an unstructured interview, there is an incomplete script; the researcher may have prepared some key questions or guidelines beforehand, but there is a need for freedom and flexibility to delve deeply in social reality [66]. The 43 local IS diagrams that resulted from the interviews, after being verified for ambiguities and uncertainties in a key informant session, were integrated into a global IS diagram using an automated algorithm named the Global Construction Algorithm (GCA) [67]. This algorithm is described in Section 4.4. The creation of the global IS diagram from the local IS diagrams ends the description phase of the MVIM method.

3.3. Data analysis: analysis phase

The global IS diagram that results from the description phase is input to the analysis phase of the MVIM method. The analysis phase in the UMCG case study consisted of two main activities. The first activity was to organize a face validation session of the global IS diagram with the key informants. A business process modelling activity is usually followed by a validation activity to check whether the created model(s) reflect(s) reality [6]. Face validation uses expert opinion to review if a model accurately reflects reality and meets user expectations [68–70]. During the face validation session, which lasted four hours, a walkthrough of the global IS diagram of the HNO care pathway was performed. The walkthrough encompassed how a patient flows through the various modelled interactions. The researchers were interrupted by the two key informants when they saw mistakes or omissions in the global IS diagram. This led to some new interactions being added. Moreover, minor changes were made to the routing, composition, and role assignment of existing interactions.

The second activity was to demonstrate the business value of the global IS diagram. This was primarily done through a process improvement analysis of the (validated) global IS diagram. In [71], the authors mention that a process improvement analysis reaps business value from models, using them to discover new insights and improvement opportunities. In the UMCG case study, the process analysis took the form of a qualitative compliance analysis in which the HNO care pathway was analyzed for bottlenecks and improvement opportunities according to a set of quality criteria related to patient care. A key informant session was used to obtain feedback on the correctness of the statements about compliance. Secondarily, the global IS diagram has practical use and value for communication and training within the HNO team. Section 5 discusses in detail the business value of the global IS diagram by discussing its purpose in communication and training, and by presenting the compliance analysis. The evaluation of the MVIM method was done by reflecting on its effectiveness and utility in the UMCG case study. The three requirements presented in Section 1 (ability to represent the interaction structure of the target healthcare HCP, ability to formalize tacit domain knowledge, and utility or business value of the method) were used as evaluation criteria. Section 6 presents the evaluation.

4. Application of the Multi-View Interaction Modelling method

4.1. Preliminaries

The application of the MVIM method in this paper is a six-step process consisting of three phases. Fig. 2 graphically depicts the flow of the method. The first state of the method is a HCP without a process definition of its human interaction structure. The first step performs a business domain analysis to scope the target business domain and to identify the human process participants (i.e. interviewees). In steps 2a and 2b, the interviews are performed to capture and model the local interaction views of the process participants. This results in multiple local IS diagrams in which the tacit domain knowledge of the interviewees is formalized. The third step in the MVIM method automatically integrates the created local IS diagrams into a single global IS diagram using GCA. The first three steps make up the process description phase of the MVIM method (see Fig. 2).

The fourth step performs face validation of the global IS diagram with (key) people from the business domain under consideration. The result after the fourth step is a global IS diagram that (1) defines the HCP under study in terms of its human interaction structure, and (2) correctly reflects reality and meets user expectations. The fifth step in the MVIM method reaps business value from the global IS diagram. In this research, the business value takes the form of identified HCP improvement opportunities. Steps 4 and 5 make up the process analysis phase of the MVIM method. The sixth step, which makes up the process redesign phase, implements the suggested improvements in the HNO care pathway. This phase is outside the scope of this paper.

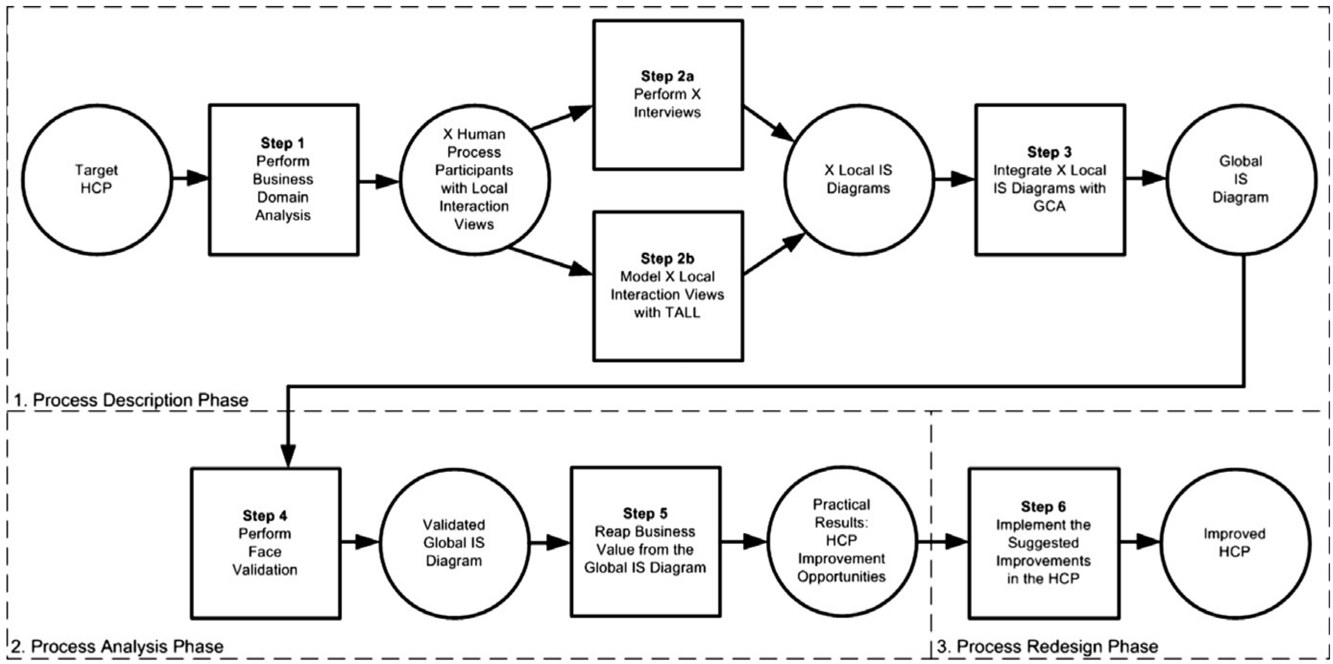

Fig. 2. Graphical representation of the steps (represented by rectangles) and states (i.e. results of steps, represented by circles) in the Multi-View Interaction Modelling method. Directed arrows connect the rectangles and circles to represent execution flow.

4.2. Business domain analysis

In the exploratory phase of the case study, as described in Section 3.2, the (para)medical disciplines/departments and the role names (i.e. job titles) involved in the HNO care pathway were identified. To minimize job interruption, the HNO steering team imposed two constraints on the researchers with regard to the interviewee selection. First, a selection of roles had to be made for the interviews. For example, the researchers were not allowed to interview ward doctors and nurses. The HNO steering team considered it sufficient to interview their direct supervisors (i.e. the nursing director/nurse practitioner and the specialist). The result was a list of 43 roles played by over 120 team members (i.e. there are multiple maxillofacial surgeon oncologists, multiple medical social workers, multiple dental hygienists, etc.). The second constraint was that the HNO steering team considered it sufficient to interview one representative of each selected role. Therefore, in the end, 43 interviewees were selected. Section 7 discusses how the imposed constraints, which influenced the data collection process, were dealt with. Most of the selected interviewees are from the four main departments involved in the HNO care pathway: Maxillofacial Surgery (MFS), ENT Surgery (ENT), Radiotherapy (RT), and Medical Oncology (MO). For the other departments, a small fraction of the personnel is concerned with head and neck oncology. The selected interviewees are represented as human agents in an AS diagram of the HNO team together with the identified organizational units (see Fig. 3).

In Fig. 3, triangle and circle icons, which appear in the top-left corner of the agent symbol, distinguish synthetic and human agents. The highest-level synthetic agent is the HNO team. The UMCG is organized de-centrally in six sectors (A–E). The second level of synthetic agents shows the four sectors. The third level of synthetic agents shows the ten departments involved in the HNO care pathway. The MFS, ENT, and MO departments contain a fourth level of synthetic agents, which represent nursing wards, polyclinics and specialist centers within departments. The other departments are polyclinical departments only (e.g. RT department) or are supportive departments (e.g. Department of Psychiatry). On the lowest level, Fig. 3 shows the 43 selected human agents as members of the different departments. Normally, human agents are specified using *name: role name* (e.g. *David Ross: Maxillofacial Surgeon Oncologist*). Here, for confidentiality reasons, no person names are used. Therefore, all human agents in Fig. 3 are depicted as anonymous instances (e.g. aMaxillofacial Surgeon Oncologist).

Next, in the case study, the high-level IS diagram of the HNO care pathway was created as indicated in Section 3.2. The diagram is included in Appendix A. As Section 3.2 mentions, the diagram depicts a general overview of the HNO care pathway in terms of its main default interactions, and served as input to the interviews to guide the interview conversation in the following ways: (i) it allowed to explain the TALL modelling notations to the interviewees, (ii) it allowed to explain, on a high level, the HNO care pathway to the interviewees (i.e. what is the planned patient journey), and (iii) it provided a starting point for the placement of the 'local' interactions of the interviewees, which is useful for large-scale HCPs like the HNO care pathway. The high-level IS diagram consists of the following default interactions:

1. *Referral*: the patient is referred to either the *maxillofacial surgeon oncologist* or the *ENT specialist oncologist* by the general practitioner, the dentist, or a specialist from another (regional) hospital.
2. *Diagnostic Day*: to limit the amount of hospital visits, the diagnostic examinations regarding a possible ailment are clustered on a diagnostic day at the *polyclinic MFS* or the *polyclinic ENT*. In the morning, the patient is seen by the specialist and several diagnostic examinations are performed (interaction *Monodisciplinary Patient Intake*). In the afternoon, specialists from the MFS, ENT, and RT departments examine the ailment in the interaction *Multidisciplinary Patient Intake Polyclinic ENT*. Based on this joint examination, the patient receives a treatment proposal at the end of the diagnostic day (interaction *Preliminary Treatment Proposal*).
3. *Additional Diagnostics*: additional diagnostics can consist of a radiology examination, a pathology examination, or additional clinical examination (e.g. an echo-guided puncture or biopsy, or an exploratory surgery under narcosis with endoscopy and possible dental extraction).

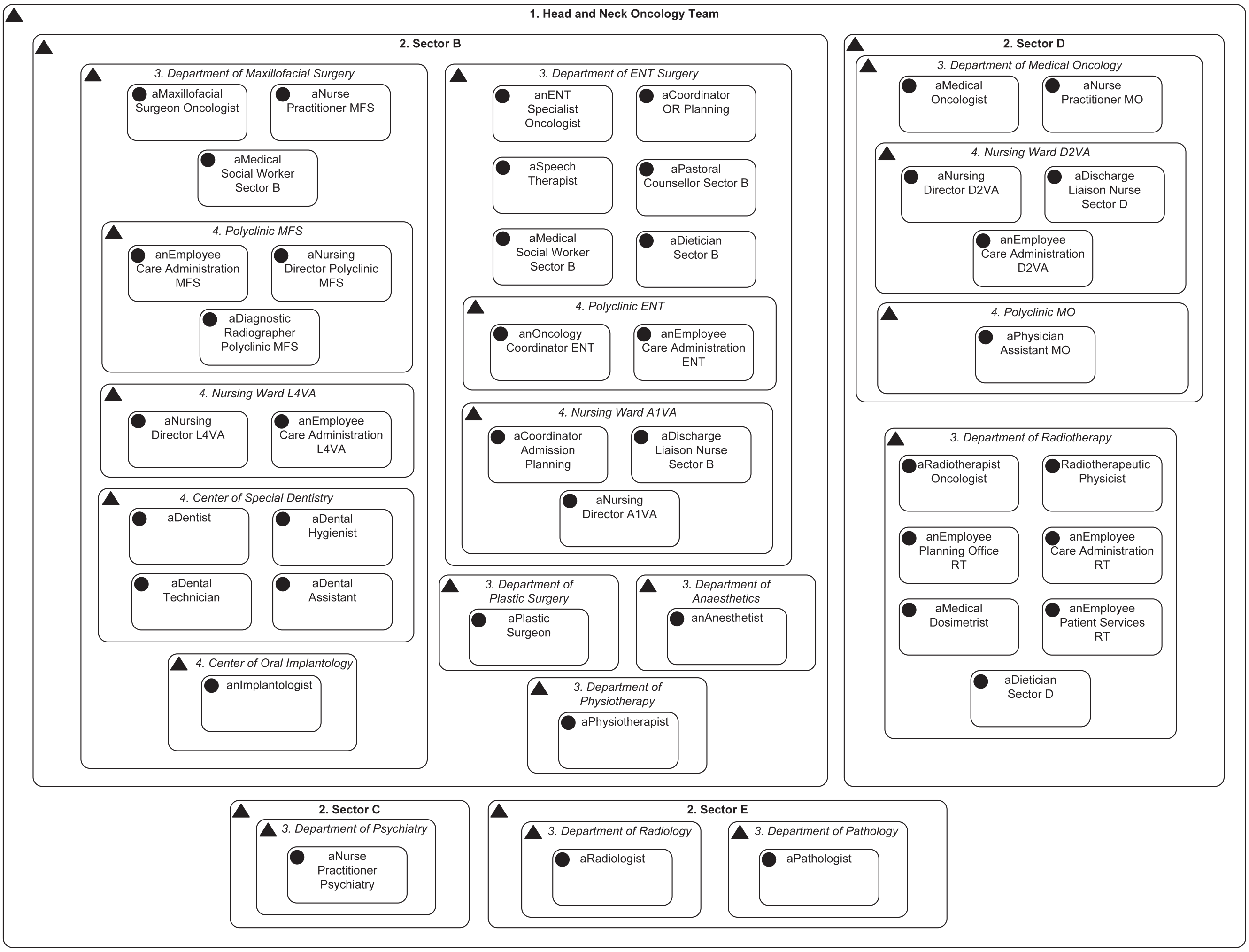

Fig. 3. The Agent Structure diagram of the head and neck oncology team.

4. *Cancer Staging:* the *maxillofacial surgeon oncologist* or the *ENT specialist oncologist* performs the clinical staging of the tumor based on the available medical information.
5. *Multidisciplinary Team Meeting*: the HNO team meets to finalize the individual treatment plan based on the clinical, radiology, and pathology examinations. The treatment plan is verified with the HNO team from the Medical Center Leeuwarden in the interaction *Teleconsulting Medical Center Leeuwarden*. If needed, also a patient reconstruction plan is made together with the plastic surgeon (reconstructive surgery), implantologist (dental implant surgery), and the dentist from the center of specialized dentistry (maxillofacial prosthetics) in the interaction *Surgical Reconstruction Meeting.*
6. *Oncological Treatment*: the basic treatments for head and neck cancer are (a) *Surgical Treatment* (maxillofacial or ENT surgery with or without reconstructive surgery), (b) *Radiotherapy* (primary or adjuvant treatment), (c) *Chemotherapy*, or (d) a combination of these like *Chemoradiotherapy* (primary or adjuvant treatment).
7. *Follow-Up Care*: regular follow-up is important after treatment to make sure the cancer has not returned or a secondary cancer has not developed. In most cases, follow-up continues for a period of five years. Follow-up includes protocolized surgery hours and medical check-ups. Furthermore, it includes counselling and recovery/rehabilitation therapy by different paramedics.

4.3. Capture and modelling of local interaction views

As described in Section 3.2, the interview process resulted in 43 local IS diagrams. Since there was limited time during the interviews, the joint modelling was first done on paper. After, in the interviewer's own time, each model was inserted into the TALL Visual Editor, a software tool to create and edit TALL diagrams (see Section 4.4), and saved as a local IS diagram. At this time, any uncertainties or ambiguities from the interviews were clarified in a key informant session since the researchers were not allowed to approach the interviewees again. The obtained feedback was processed in the local IS diagrams.

Fig. 4 depicts one local IS diagram from the set of 43 diagrams.[7] This specific diagram depicts the local interaction view of the *Radiotherapeutic Physicist*. The (local) interactions in this diagram detail the interaction *Pre-Treatment Period RT*, one of the interactions in the high-level IS diagram of the HNO care pathway (see Appendix A). The pre-treatment period at RT is mainly concerned with the creation of a radiation treatment plan. The interaction structure in Fig. 4 reveals that the *Radiotherapeutic Physicist* is concerned with the technical assessment of the radiation treatment plan (interaction *Technical Assessment RT Treatment Plan*), which checks if the radiation machine can execute the plan. To complete this interaction, the

[7] All original 43 local IS diagrams of the HNO care pathway are in Dutch. Thus, all interaction and role names in Fig. 4 have been translated from Dutch to English.

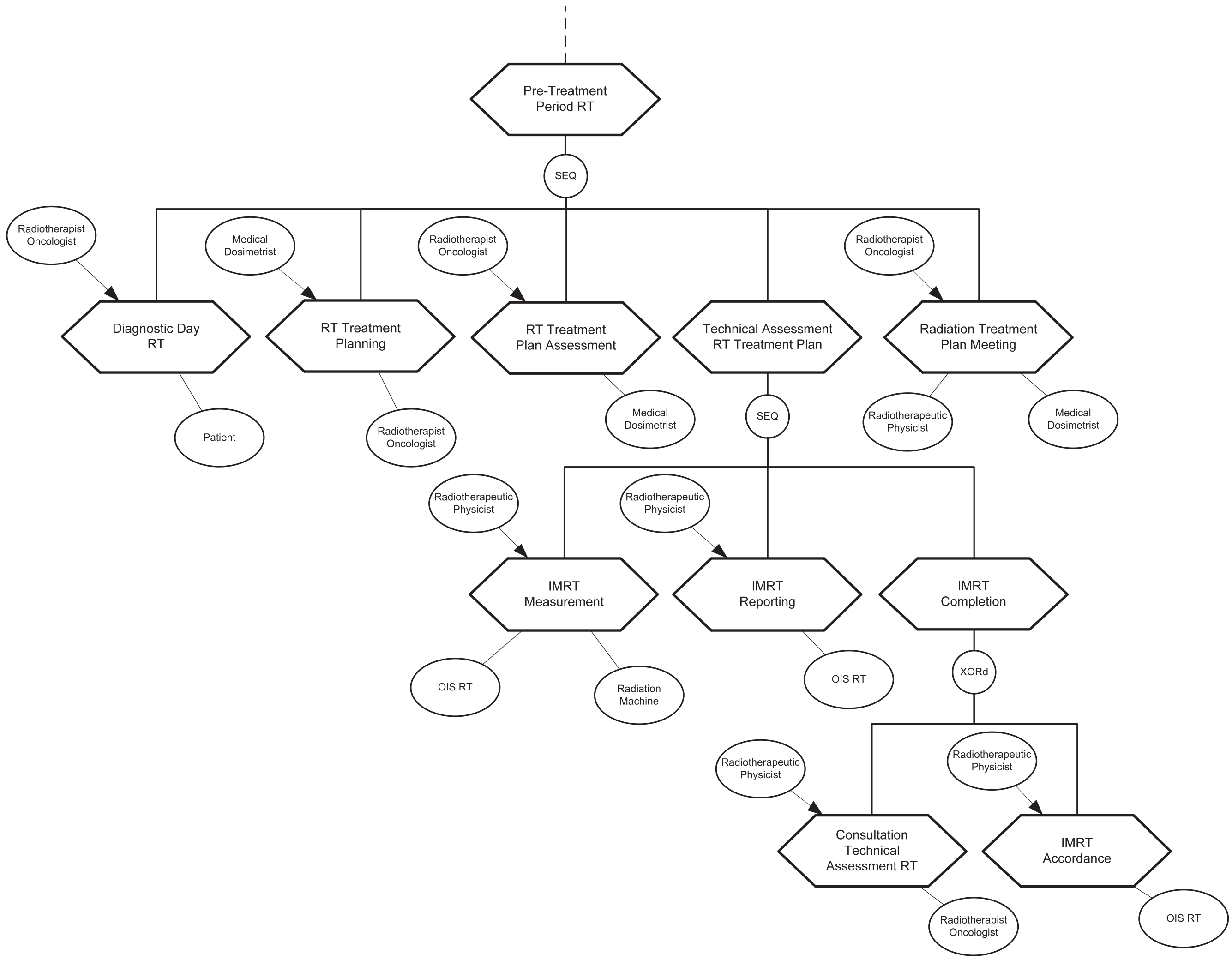

Fig. 4. The local interaction structure diagram of the *Radiotherapeutic Physicist*.

Radiotherapeutic Physicist initiates several sequential child interactions: *IMRT Measurement* (transfer to and measurement of the radiation treatment plan on the radiation machine), *IMRT Reporting* (formal registration of the results of the IMRT measurement), and *IMRT Completion*. The latter interaction consists of two exclusive conditional interactions: a consultation with the *Radiotherapist Oncologist* in case any anomalies have been found during the IMRT measurement (interaction *Consultation Technical Assessment RT*) or a formal approval of the radiation treatment plan when no anomalies have been found (interaction *IMRT Accordance*).

Besides the above-mentioned interactions, Fig. 4 shows that the *Radiotherapeutic Physicist* is knowledgeable about three interactions that are performed by colleagues before the technical assessment of the radiation treatment plan:

- *Diagnostic Day RT*: patient intake at RT by the *Radiotherapist Oncologist*.
- *RT Treatment Planning*: creation of the radiation treatment plan by the *Medical Dosimetrist* based on the prescription of the *Radiotherapist Oncologist*.
- *RT Treatment Plan Assessment*: functional assessment of the radiation treatment plan by the *Radiotherapist Oncologist*.

Finally, Fig. 4 shows that the *Radiotherapeutic Physicist* is involved in the interaction *Radiation Treatment Plan Meeting*. In this meeting, which is led by the *Radiotherapist Oncologist* (see the initiator role in Fig. 4), radiation treatment plans are presented and double-checked before radiation treatment actually starts. The roles in Fig. 4 depict the generic interaction participants the *Radiotherapeutic Physicist* knows of. The role *OIS RT* stands for Oncology Information System Radiotherapy. In the TALL modelling language, an information system can be represented as an interaction participant [19].

Each local IS diagram represents a specific local (incomplete) part of the overall HCP, which complement each other. For example, with regard to the pre-treatment period at RT, the local IS diagram of the *Employee Care Administration RT* is more specific about the interactions that occur during the diagnostic day at RT. Similarly, the local IS diagram of the *Medical Dosimetrist* is more specific about the treatment planning at RT. Depending on the interviewee and its (para)medical discipline or department, the other 42 local IS diagrams detail other treatments and phases in the HNO care pathway. All 43 local IS diagrams can be downloaded together with the TALL Visual Editor, which is discussed in the next section.

4.4. Integration of local interaction views

The MVIM method utilizes GCA to automatically integrate multiple local IS diagrams into a single global IS diagram. GCA integrates interactions, their relations, their roles, and their attributes. It can integrate complementary or alternative interaction structures (i.e. differences in local IS diagrams), and merge overlapping interaction structures (i.e. commonalities in local IS diagrams). The reader is referred to [67] for a detailed technical description of the workings of GCA. During the face validation session of the global IS diagram of the HNO care pathway, as described in Section 3.3, the key informants also indicated redundant interactions, which were the result of ontology conflicts [72]. In GCA, interactions and roles are candidates for merging when their labels are identical. However, different interviewees may use different (medical) terms or terminology for the same interactions and roles. A simple example from the case study is the interaction *Morning Nursing Ward Meeting*, which was named *Morning Patient Discussion* by some interviewees. In only a few cases, the key informants found redundant interactions.

A software toolset supports the MVIM method. The TALL Visual Editor allows the user to build and edit TALL diagrams. The editor stores TALL diagrams and its modelling elements in an associated database. In the face validation session, all key informant feedback was processed live in the global IS diagram using the editor. A software tool that implements GCA, named Local IS Integrator (LISI), has been developed. LISI operates on the database created by the Visual Editor. With LISI, the user can integrate a selected number of local IS diagrams into a single global IS diagram, which the tool saves as an additional diagram in the database. The user can then load the database in the Visual Editor to visualize the global IS diagram. Fig. 5 shows the main user interface of LISI. The 43 local IS diagrams of the HNO care pathway were integrated using LISI. Appendix B shows a screenshot of the Visual Editor with a fragment of the produced global IS diagram of the HNO care pathway. The complete global IS diagram consists of 410 unique interactions and 157 unique roles, and is included in the download of the Visual Editor. Note that, all original case study diagrams (i.e. the local and the global IS diagrams), which are available online, are in Dutch. All software tools are freely available from the software section on http://www.agentlab.nl/.

5. Business value: practical results

The global IS diagram provides an integrated end-to-end overview of the interactions in the HNO care pathway. Now that the interactions in the HNO care pathway are defined in a model, the HNO care pathway becomes amenable to analysis. Business value can be reaped from the global IS diagram, by using it to discover HCP improvement opportunities. This section realizes two model purposes of the global IS diagram, which generate business value.

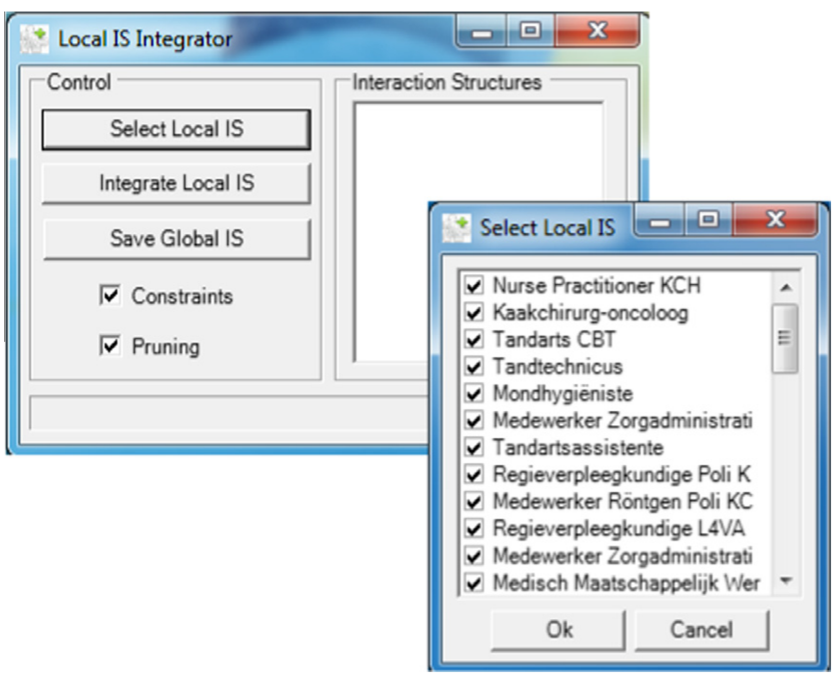

Fig. 5. The user interface of the integrator for local interaction structure diagrams.

Table 1
The quality criteria that are input to the compliance analysis.

1	Systematic screening of patient symptoms and complaints, and referral to the appropriate medical professional or paramedic in an early stadium throughout all phases of the care pathway[a]
2	All patients are offered adequate follow-up care: • Tailored recovery- and rehabilitation therapy is offered • Adequate referral and transfer to primary care in the home environment
3	Every (non-critical) HNO patient is proposed an individual treatment plan, which has been discussed in a multidisciplinary meeting before treatment starts
4	The specialist or doctor informs the patient and his/her key relatives about the results of the oncological treatment immediately after the treatment
5	Throughout all phases of the care pathway, it is clear to the patient and his/her key relatives who their contact person is in case of questions and/or problems
6	Key relatives are involved as much as possible based on the wishes of the patient. If needed, key relatives receive professional support
7	Prior to patient discharge, a concluding consultation with the (oncology) nurse and/or ward doctor takes place
8	The possibility of a visit by a fellow sufferer (i.e. ex-patient) is pro-actively brought to the attention of the patient
9	To minimize patient hospital visits, diagnostic examinations are clustered on one day and location as much as possible
10	Good coordination and (digital) information-exchange takes place between healthcare workers. Clinicians have 24-h direct access to relevant medical data and reports

[a] Diagnostic phase, hospitalization/treatment phase, and follow-up phase.

5.1. Compliance analysis

As mentioned in Section 3.1, the HNO team participates in the NWHHT, whose primary goal is to improve the quality of the HNO care in the Netherlands. The HNO team strives to comply with the NWHHT guidelines to remain an acknowledged and certified HNO treatment center. Moreover, the HNO team realizes strongly that the improvement of the HNO care pathway is a continuous process. In the healthcare domain, quality of care is often associated to and determined by the needs of the patient. A recent report from two Dutch HNO patient associations [73], written in cooperation with the NWHHT, formulates quality criteria from the patients' viewpoint (from now on: the HNO report). Table 1 presents ten quality criteria from the HNO report, which were selected based on the scope of the current study.

Compliance management or regulatory compliance is about the need of organizations to check their compliance with relevant laws, regulations, and procedures [74]. A compliance analysis is used to investigate compliance of the HNO care pathway with the quality criteria in Table 1. For each quality criterion, the compliance analysis identifies (lack of) relevant interaction structures in the global IS diagram of the HNO care pathway. Then, it makes a statement about compliance and suggests organization improvement actions when necessary. To verify the statements about compliance with the quality criteria, key informant sessions were used to discuss and illuminate the identified interaction structures, and make sure that useful improvements are suggested. For confidentiality reasons, the full compliance analysis is not included in this paper. In general, the compliance analysis reveals that the HNO care pathway is a coordinated and integrated whole of interactions. However, for some of the quality criteria, improvement actions are suggested. For these criteria, Appendix C presents a summary of the results of the compliance analysis, the key informant sessions, and the suggested improvement actions.

5.2. Communication and training

Currently, the HNO team members have their own local views of the HNO care pathway. The global IS diagram of the HNO care pathway reflects the formalized and consolidated domain knowledge or understanding of the interviewed HNO team members. The business value of the global IS diagram is its ability to communicate that understanding to all healthcare workers (and any other stakeholders). It is important for all involved healthcare workers to have a good understanding of the global interaction structure of the HNO care pathway because:

- to improve coordination, integration, and continuity of care, it is important that healthcare workers understand the interactions and responsibilities of colleagues both within and across (para)medical disciplines and departments (i.e. who delivers which care and when);
- to better assess a patient's needs and emotional condition, and to improve quality of care, it is important that healthcare workers understand the patient's complete journey through the care pathway.

The suggested organization improvement action is to make HNO team members knowledgeable of the HNO care pathway via the global IS diagram. Ideally, this is part of a training course for (new) healthcare workers. The business value of such a training course is that employees are better informed in individual patient contact and in interactions with colleagues. Moreover, employees are in a better position to participate in process improvement projects or even to implement (local) improvements in daily work practice themselves.

6. Evaluation

According to [75], a design solution is effective when it satisfies the requirements and constraints of the problem it was meant to solve. The objective of this paper was to introduce, apply, and evaluate a novel modelling method that fits the HNO care pathway, and addresses the organizational problem. The core of the organizational problem is the implicit interaction structure of the HNO care pathway, and the resulting lack of a proper basis for its analysis and improvement. The evaluation described in this section is a reflection on the effectiveness of the (application of the) MVIM method. The requirements put forward in Section 1 and the characteristics of the HNO care pathway listed in Section 3.1 are used as measures for the success of the evaluation.

The **first requirement** is that the MVIM method should be able to describe the interaction structure of the HNO care pathway. The interaction-centricity of the MVIM method, which is the result of the use of the TALL modelling language, proved advantageous in the case application. This because the focus of the modelling effort was to describe the interactions between the healthcare workers rather than the development of a step-by-step task model. Thus, the TALL modelling language proved well suited for the description of the target HCP's interaction structure. In this regard, the language suits the collaborative nature of the HNO care pathway (characteristic one). In particular, the tree layout of the IS diagram, with the possibility to specify different routings between interactions, proved an effective way to tackle the complexity of the HNO care pathway (characteristic three). This confirms previous research into the effectiveness of tree-based representations [76,77]. Moreover, the interaction-centricity enabled the modellers to focus on the essential interactions in the HNO care pathway, which are more stable. In other words, the interaction specification is independent of the dynamic realization of the interactions through the execution of individual tasks. Thus, the IS diagram allows to specify *what* to perform without specifying *how* to perform it. This allowed to address the dynamic nature of the HNO care pathway (characteristic four). As indicated in Section 3.1, exceptions are an important part of healthcare collaboration. Exceptions commonly occur (unexpectedly) during interaction execution. Section 2.1 explains that interactions are performed by the local behaviors of the interaction participants. Thus, the trigger to start a new interaction for exception handling occurs at the behavior level. This implies that, in an execution context, the IS diagram is a (partly) emergent artefact since interactions may take place that were not modelled in advance, or modelled interactions may not complete or occur at all. The use of the IS diagram in a (system) execution context has not been the focus of this paper. However, it is discussed in Section 8 as an important part of future work. The point here is that GCA, which is used by the MVIM method to automatically integrate multiple local IS diagrams into a single global IS diagram, can also be used at execution time to support on-the-fly (structural) change of the IS diagram when an eventual software system for HCP support is in place [19,67]. After execution, the IS diagram may then serves as an execution log of the interactions in the target HCP. In this regard, the XOR and XOR_d routing constructs in the IS diagram allow to include and traverse exceptions, being alternative executions, straightforwardly.

The **second requirement** is that the MVIM method should facilitate the externalization and formalization of the tacit domain knowledge of the HNO team members in graphical process models. The multi-view support provided the ability to capture and model the local interaction views of the interviewed HNO team members in 43 local IS diagrams. Since the TALL modelling effort starts from a local viewpoint, the MVIM method is a decentralized modelling method. This matches the multidisciplinary (i.e. decentralized) nature of the HNO care pathway (characteristic two). Moreover, the multi-view support provided the following benefits in addressing the complexity of the HNO care pathway (characteristic three):

- The modeller(s) could focus on segments (i.e. local IS diagrams), which were then automatically integrated to form a whole (i.e. global IS diagram). This divide-and-conquer strategy proved effective in practice.
- The interviews took the form of mini-workshops in which the modeller created each local IS diagram in active cooperation with the interviewee. This had the advantage of immediate validation. Moreover, the modeller nor the interviewee did have to create the local IS diagrams alone.
- The individual nature of the local IS diagrams created a sense of ownership among the interviewees. This fuelled their interest and involvement, which led to more precise diagrams.

The automatic integration, using GCA, of the 43 local IS diagrams into a single global IS diagram of the HNO care pathway provided the following benefits:

- Two modellers used interviews to create the 43 local IS diagrams as input for GCA. There was no need for the modellers to discuss or agree with each other. In theory, an entire team of process modellers, who work independently and concurrently, can execute the modelling effort. This is especially useful for large-scale HCPs (characteristic five).
- The integration of the 43 local IS diagrams was done by GCA, an algorithm, instead of being done by a human modeller. This ensured that all local interaction views were properly consolidated in the global IS diagram.

The integration of the local IS diagrams into a global IS diagram can be done in two ways: automatic by using GCA or manual by the (lead) human modeller. In this research, the automatic way was chosen for two reasons. First, the modeller, who is also playing the interviewer and organization observer role, may be influenced by the various local views and opinions and hereby introduce a bias in the result – for example shifting the global view towards one or another local view. In other words, the modeller is not a neutral entity. The advantage of applying GCA is that no aspects of the local views are lost because the integration rules are consistently applied (i.e. fair treatment of local views, only duplications and/or overlaps are pruned for the global IS diagram). In this sense, one can consider the application of GCA as a neutral approach – recommended for any application of the MVIM method. Second, for large-scale HCPs like the HNO care pathway, mistakes are likely to be made by a human modeller because of the large number of local IS diagrams that have to be integrated. In this regard, the advantage of GCA is that the integration is rigorous.

The **third requirement** is that the application of the MVIM method should contribute to an improvement of the HNO care pathway. The practical results in Section 5 demonstrate that the global IS diagram, which is produced by the MVIM method, brings business value. The reflection above reveals that the MVIM method suits the characteristics of the HNO care pathway and meets the requirements set out in advance. The MVIM method successfully brings explicitness to the HNO care pathway in terms of the proper capture and modelling of its interaction structure, which opened up the door for proper analysis and improvement.

7. Discussion

The healthcare HCP studied in the UMCG case study is representative of other medical diagnosis and treatment processes, which are concerned with patients with a chronic disease. In such HCPs, healthcare workers are motivated or pressured to collaborate in a multidisciplinary team for effective long-term treatment. There is a trend to organize such processes in care pathways [78,79]. Although other healthcare HCPs might differ in scale and degree of complexity, in general, they share the characteristics of the HNO care pathway: collaborative, multidisciplinary, complex, dynamic, and large-scale. Thus, the MVIM method can be beneficial in the broader healthcare domain.

Multidisciplinary collaboration is not self-evident in the healthcare domain [59]. The details of the practical results in Appendix C show that multidisciplinary collaboration is not always effective in the HNO care pathway, especially in the transfer periods between different (para)medical disciplines or departments. However, both medical professionals and patient organizations increasingly consider multidisciplinary collaboration a necessity to improve quality of care. In line with this development, there is a move towards more flexible organizational structures with a focus on teamwork and healthcare collaboration [12]. The interest of the HNO steering team in the current research shows that initiatives to improve healthcare collaboration are considered important.

The collaborative nature of healthcare HCPs is characterized by less certainty, more ambiguity, and more complexity. To facilitate the improvement of healthcare HCPs, modelling tools that suit their nature are needed to make them explicit and amenable to analysis. To make healthcare HCPs explicit, the tacit domain knowledge of the involved healthcare workers needs to be made explicit (in models). The MVIM method can be used for this purpose.

In healthcare organizations, hospitals in particular, care protocols exist. Care protocols are treatment recommendations that are most often based on guidelines [80]. These protocols are usually enacted in a top-down manner as to reduce variation in treatment and outcomes, and to maintain or improve quality of care [81]. As mentioned in Section 3.1, the NWHHT develops national guidelines for head and neck cancer care in the Netherlands. A care protocol is an outline of planned care but not a record of what happens in practice. Thus, with regard to existing care protocols in healthcare organizations, the role of the MVIM method is to collect reality through the bottom-up capture and modelling of local interaction views. After integration, the global interaction view provides a rich description of actual human interaction that can be used to identify process improvement opportunities. The identified improvement opportunities may be used to revise existing care protocols or to inform the development of new care protocols.

The paradigm shift towards interaction-centric process design may have implications for healthcare practice and management, and the possible future (re)design of healthcare systems:

- structural implications: blurring of organizational boundaries;
- decisional implications: changing planning and management systems;
- financial implications: changing funding mechanisms, budget cycles, and resource flows;
- professional implications: changing roles and responsibilities.

A perceived limitation in the case study was the imposed constraint to select one representative from a subset of roles for the interviews. This may have posed the risk that valuable (tacit) domain knowledge was not collected and therefore the global IS diagram is less accurate. In the case study, this limitation was addressed through face validation of the global IS diagram with the key informants. Still, even the key informants have local (i.e. restricted) views. Therefore, the MVIM method is most advantageous when the business domain under consideration allows all (relevant) healthcare workers to be interviewed.

8. Conclusions and future work

In the healthcare domain, HCPs require interaction between healthcare workers from different (para)medical units in both diagnosis and treatment. Typical healthcare HCPs are concerned with effective long-term treatment of patients with a chronic disease. Healthcare HCPs are an essential part of modern healthcare organizations, hospitals in particular. Thus, it is important for managers to have a deep understanding of the functioning of HCPs, as a necessary precursor to improve their effectiveness and/or to develop IT for their support. A common way to increase understanding of processes is to conduct a business process study in which a business process is defined in a model using a graphical modelling language after which the model is analyzed to identify improvement opportunities. This paper argues that the representation of human interaction structures is weak in existing workflow-based process modelling tools, which are most commonly applied in healthcare process management. These tools are most effective when the business activity is repetitive and well-structured (e.g. clinical workflows). As a result, workflow models usually focus on the task (performed by a single actor) instead of the interaction (performed by multiple actors).

This paper reports on a business process study of a healthcare HCP at a Dutch academic hospital in which a novel Multi-View Interaction Modelling (MVIM) method is introduced, applied, and evaluated. The MVIM method utilizes the interaction-centric TALL business process modelling language to describe the target HCP's human interaction structure (i.e. the interactions, their composition and routing relations, and their roles). The selected healthcare HCP is the head and neck oncology care pathway in which a multidisciplinary team of healthcare workers from over 40 (para)medical disciplines collaborates. The addressed organizational problem is that there is no process definition and managerial awareness of the interactions in the selected healthcare HCP. As a result, there is no proper basis for process analysis and improvement. Improvement is considered important to increase integration, continuity, and quality of the provided care.

The interaction-centricity of the MVIM method, which is the result of the use of the TALL modelling language, matches the different nature of the business activity in (healthcare) HCPs (i.e. collaboration instead of task sequence). The evaluation results show that the method is a useful and effective tool to capture and model the target HCP's human interaction structure. In the medical profession, healthcare workers develop specialized (tacit) domain knowledge within their own functional areas. Besides the effective description capability, the MVIM method is proven effective to (1) collect and formalize the tacit domain knowledge of interviewed healthcare workers in local (i.e. individual) interaction diagrams and (2) generate automatically a single integrated global interaction diagram based on the local interaction diagrams. In this way, the method takes advantage of the distributed knowledge of the subject matter experts, which leads to a more accurate and complete global interaction diagram. Subsequent qualitative interaction analysis of the global interaction diagram demonstrates its business value through the identification of several desirable process improvement opportunities. Based on its identified characteristics, this research concludes that the studied healthcare HCP is representative of most care pathways and/or medical diagnosis and treatment processes. Thus, the MVIM method is expected to be useful in the broader healthcare domain. When used more widely, interaction-centric modelling tools like the MVIM method may have implications for the (re)organization and management of (future) healthcare systems.

An interesting avenue for future research is to investigate or include the patient's view of the studied healthcare HCP. In this regard, shadowing may be used as a research method to observe the collaboration from the patient's point of view. Shadowing is a qualitative research technique, which involves a researcher closely following a member of an organization over an extended period of time [82]. The researcher unobtrusively records the what, when, where, and how the subjects perform its activities in the real world [35].

The next step with the MVIM method is to strengthen the evaluation through crosschecking and replication of the successful results from the hospital case study. Although the HCP studied in this paper is not atypical, other cases from both the healthcare domain and other domains need to be performed. This allows to examine the method's capabilities, and to improve and/or extend its design. One of the goals is to explore the use of other data collection methods for the interaction capture from the human process participants. The future case studies are planned to include the application of workflow-based process modelling languages to demonstrate that these are less effective for the modelling of HCPs, as compared to the TALL modelling language. Moreover, in future healthcare case studies, the IS diagram created in a first modelling phase is to be used as an effective base for the agent behavior modelling in a second modelling phase. This allows deficiencies and/or innovations within and across local agent behaviors to be identified, which can improve collaboration and interaction on the behavior level, as demonstrated in [20] for a Dutch municipality.

When the MVIM method is to be useful to organizations over a longer period, it should be possible to quickly update the global IS diagram to reflect new (local) work practices. To achieve this, the local IS diagrams can be maintained by the organization and updated when (local) change occurs. A new global IS diagram can then be automatically generated using the MVIM method. Overall, all the TALL diagrams should be easy to maintain, inspect, use, change, compare, and integrate. Therefore, future research will focus on the development of an interactive (multi-user) diagram management system, which includes the current diagram editor and integrator for local IS diagrams. As an extension, this system may use the global IS diagram to monitor the execution of the interactions in a given HCP. In this context, a log of an executed HCP can contain various temporal data like interaction start and end times. Such data can be used for quantitative analysis to identify and address bottlenecks and delays. To support such an analysis, future work plans to develop a time-based visualization for the TALL IS diagram, in which interactions are laid out on a time axis. The TALL modelling language is already extended with temporal interaction attributes. Another long-term goal is to apply interaction-centric process modelling methods and languages – like the MVIM method and the TALL modelling language – as the first phase in the development of multi-agent systems that support HCPs.

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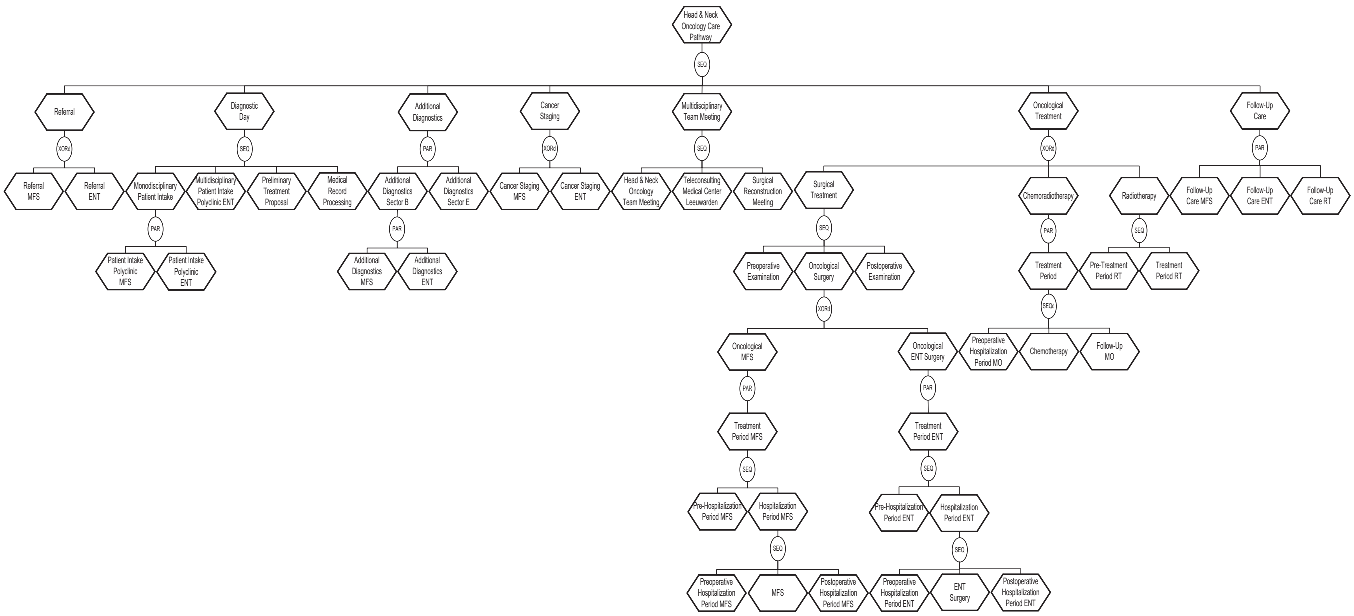
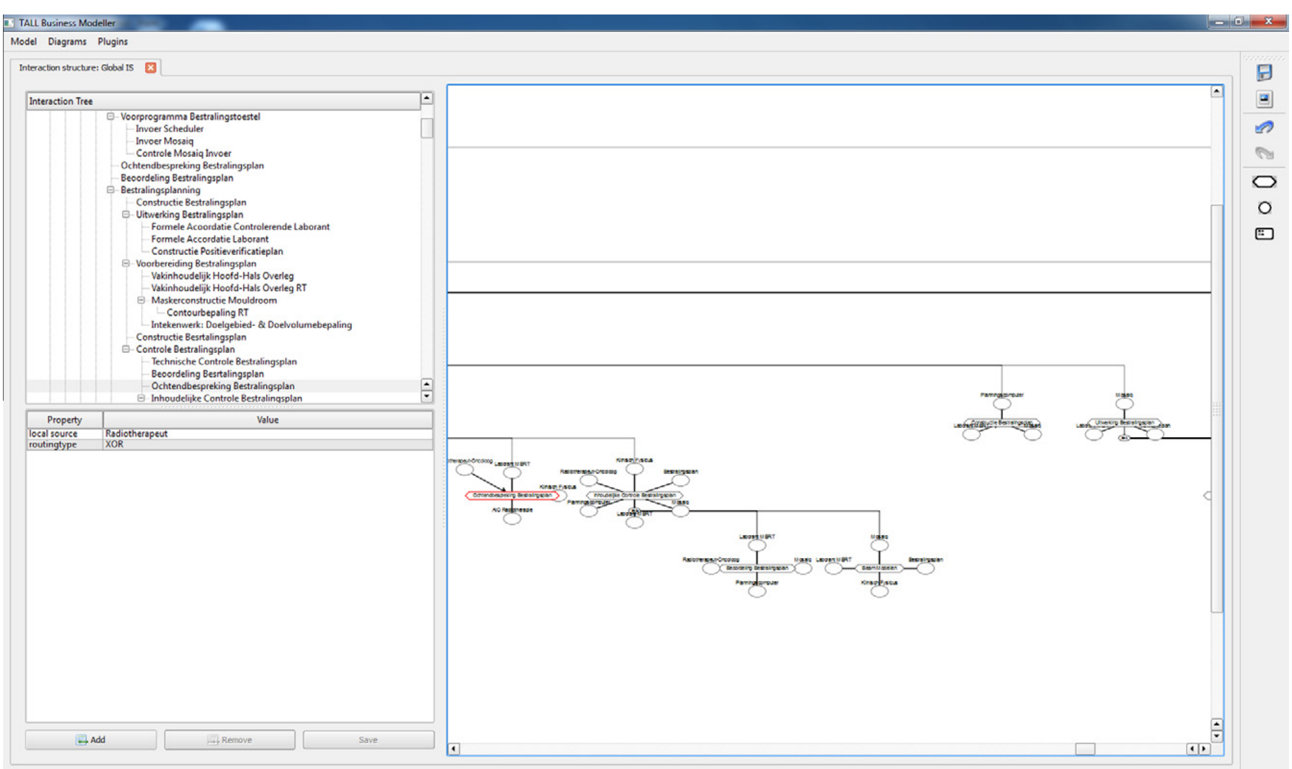
Appendix A

The high-level interaction structure diagram of the head and neck oncology care pathway.[8]



Appendix B

The global interaction structure diagram of the head and neck oncology care pathway in the TALL Visual Editor.



8 The original diagram is in Dutch. All interaction names have been translated from Dutch to English.

Appendix C

Details of the practical results.

Quality Criterion From Table 1	Suggested Improvement Actions
1	The following paramedics are present in the HNO team: Dietician (for nutrition and weight problems), Medical Social Worker and Nurse Practitioner Psychiatry (for psychosocial problems), Pastoral Counsellor (for spiritual and religious problems), Discharge Liaison Nurse (for home care management), Speech Therapist (for speech and swallowing problems), Physiotherapist (for problems with the locomotor apparatus), Dental Hygienist (for oral and dental care). The global IS diagram of the HNO care pathway shows that interactions between paramedics and patients are most prominent in the hospitalization/treatment and follow-up phases. Thus, paramedics are not systematically involved in the diagnostic phase thus depending on the judgment of the physicians and nurses for referral. However, these healthcare workers are not educated to make adequate paramedical diagnoses. The **suggested improvement action**, on the longer term, is to bring forward and/or protocolize the paramedic process, preferably on the first diagnostic day. This allows paramedics to filter out more patients and initiate timely counselling and/or therapy. This applies especially to the following paramedics: • Pastoral Counsellor: the pastoral assessment is protocolized for ENT patients with laryngeal cancer during pre-operative hospitalization. For other patients, spiritual or religious problems are to be diagnosed by the physicians or nurses; • Medical Social Worker Sector B: there is insufficient insight into the psychosocial needs of non-surgical ENT patients (e.g. primary RT patients). After referral to RT by the lead clinician, the medical social worker in Sector B often never sees them again. There is no dedicated medical social worker in Sector D (i.e. RT); • Discharge Liaison Nurse Sector B: for MFS and ENT patients, this nurse arranges home care during hospitalization close to patient discharge. In this way, home care needs of patients who are not hospitalized or who require home care before hospitalization are not property assessed; • Dietician Sector B: the ward nurse screens the MFS and ENT patients during the admission conversation using the MUST (Malnutrition Universal Screening Tool). This screening is not performed at the diagnostic day, which means dietary consultations may be scheduled too late; It is hard to protocolize the paramedic process for all patients because of the large population. Therefore, the **suggested organization improvement action**, on the short term, is the systematic use of screening lists by physicians and nurses in all phases of the care pathway. Screening lists allow patients to 'self-screen' themselves and communicate their needs to healthcare workers. These lists help to clarify and sharpen referral criteria, especially in the diagnostic phase.
2	The global IS diagram of the HNO care pathway shows that follow-up care is well organized with regular doctor-patient (i.e. medical check-ups) and paramedic-patient interactions. Patients are mostly treated in-house to provide adequate follow-up care. Referral to primary healthcare in the home environment is only done when travel distance or patient conditions inhibit frequent treatment by the HNO team. The global IS diagram shows that several, but not all, paramedic-patient interactions run in parallel with the doctor-patient interactions. The **suggested improvement action** is to improve alignment and coordination during follow-up care to reduce patient hospital visits. There are currently initiatives to set up a joint polyclinic for the MFS, ENT, and RT departments.
5	During periods at specific departments, the global IS diagram includes several interactions between specialist nurses and patients to provide overall guidance. It is clear to the patient whom to contact during these periods. However, during transfer from one to another department, which is often a home period, it is not clear whom to contact. The **suggested improvement action** is to appoint a case manager at the first diagnostic day who remains the primary contact person throughout the entire care pathway.
9	The global IS diagram of the HNO care pathway shows that most diagnostic examinations are clustered on the first diagnostic day. This successfully reduces the number of patient hospital visits. Some diagnostic examinations, especially medical imaging, are not performed on the first diagnostic day. Delays occur because demand is bigger than supply. This makes it difficult to finalize the treatment plan for the patient in a timely fashion. The **suggested improvement action** is to arrange fixed time slots for medical imaging. Another **suggested improvement action** is to ask maxillofacial surgeons and ENT specialists in regional hospitals, from where some patients are referred, to perform and share medical imaging results.
10	Analysis of the roles in the global IS diagram of the HNO care pathway reveals that IT systems are used for digital reporting and appointment scheduling. However, the inserted information is quite limited, especially in the diagnostic phase. Thus, important medical information (e.g. medical history, medication, preliminary treatment, home situation, psychosocial problems etc.) is not available for all disciplines from the start. This is ineffective especially when medical decisions have to be made. For example, in the case of adjuvant radiotherapy after maxillofacial surgery, RT would like to be able to examine all medical information collected in the diagnostic and treatment period at MFS. The **suggested improvement action** is to improve reporting and information sharing across disciplines. This avoids needless repetition of anamnesis. There are currently initiatives to protocolize the timely availability of medical information. The global IS diagram reveals that the hospital-wide appointment scheduling system is not involved in the interactions at RT. The complex radiation planning procedures and schemes require the use of proprietary systems. The result is that other disciplines cannot effectively follow RT patients and/or cluster appointments during combined treatment. This is especially important for MO in the case of chemoradiotherapy and for the dental hygienists from MFS, who have daily interactions with the RT patients for oral and dental care during radiation treatment. The **suggested improvement action** on the long term is to investigate the suitability of the appointment scheduling system for use at RT. On the short term, the **suggested improvement action** is to give a selection of personnel access to the proprietary systems of RT.

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